

Ready, Set, Go? Impact of the Pandemic on Student Readiness: Laboratories, Preparedness, and Support

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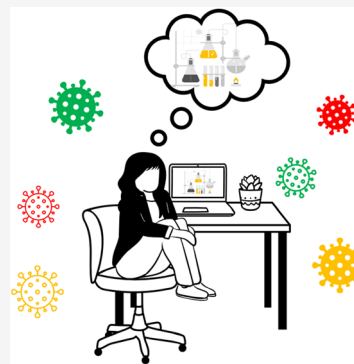
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ABSTRACT: There is little doubt that the pandemic has had a significant impact on students' academic achievement and mental health across the K–16 spectrum. For undergraduate chemistry instructors, data on the number of laboratories students completed in high school and in what mode would be important information in considering what modifications could be implemented in the laboratory curriculum and in messaging about the laboratory activities. Additionally, shedding light on how prepared students feel to succeed at college work, how the pandemic has impacted their preparedness for learning, and what the chemistry community can do to support student learning can shape messaging on the first day and for subsequent activities in the course. An initial and final course survey that sought to shed light on these student experiences and perspectives will be discussed along with the impact on course messaging and structure.



KEYWORDS: First-Year Undergraduate/General, General Chemistry, Laboratory, Curriculum, Laboratory-Instruction, Distance Learning/Self Instruction, Student-Centered Learning

INTRODUCTION

During the COVID-19 pandemic, education across all levels was impacted. Although many facets of society seem to be recovering from the pandemic, student learning will continue to feel the pandemic's effects for years to come. Initial research of the impact of COVID-19 on education reports continued disruptions to learning into the 2021–2022 academic year,^{1–3} and a significant gap in test scores for students in grades 3–8 were 0.20–0.27 standard deviations lower than students in the same grade in Fall of 2019, before the pandemic. To contextualize this data, these decreases are larger than those estimated for the disruption caused by Hurricane Katrina.³ Perhaps, most concerning is the test-score gap between low-poverty and high-poverty elementary schools where the gap grew by 20% mostly during the 2020–2021 school year.³ Although there is recovery present in the 2021–2022 data, historically marginalized students and students at high-poverty schools continue to show larger gaps in mathematical achievement.^{1–3} Repeatedly, the data demonstrates the differential impact of the pandemic on achievement in math and reading in grades 1–8 based upon race/ethnicity and school poverty classification.

Kuhfeld and Lewis³ have calculated the number of years needed to close the achievement gaps based upon initial recoveries measured between Spring 2021 and Spring 2022. In mathematics, the years required to close the gap for 5–8 graders is more than 5 years, which implies that some students will not fully recover from the impacts of COVID on their

mathematical achievement before they graduate from high school. Transferring this unfinished learning on to high school students transitioning into college is of great concern.

There are also emerging concerns around students' sense of identity and mental health of students.^{4,5} During middle school and high school, social and emotional learning becomes centered on the formation of identity and empathetic skills. Students in these years can form a stronger sense of self, of what they value, and what their identity will become in future years. The pandemic disrupted the experiences that students might use to form a sense of identity—course work, laboratories, project-based learning, experiential learning experiences, social experiences, and/or school trips. Thus, faculty should not be surprised if students change their majors more readily or perhaps arrive at college thinking that they want to be a STEM major with little experience in the laboratory.

Mental health issues have been an increasing concern on college campuses prior to the pandemic.^{5,6} The disruption in school life, home life, and the loss of loved ones are only three types of challenges students faced in the pandemic. Students in

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chemistry classrooms come to college with a broader range of needs, challenges, and abilities than ever before. Thinking about how to support student success, connecting them with resources that not only promote academic success but also support mental health and well-being before a crisis occurs is critical.

Although communities in higher education have been discussing the pandemic's impact on student readiness,^{6,7} there has been little focus on missed learning: the lost opportunities to develop essential content and academic skills needed to be successful, such as study skills for different subjects that were underexplored due to disruptions in learning and remote learning—especially in preparation for college. High school students who were in their sophomore, junior, or senior years during the pandemic did not have the normal education or experience students have as they transition to college—and in general chemistry courses, it was evident, especially in the laboratory.^{8–14}

Given this emerging literature and context, this report seeks to share student hands-on laboratory experiences before and during the pandemic prior to enrolling in college for the purposes of reflecting on what can be done to address areas of concern. Second, this report seeks to share student voices responding to a prompt designed to elicit their recommendations and advice for incoming students seeking to be academically successful. The data and analyses herein provide actionable ideas to support student success and to further understand the impact of COVID-19 on students in general chemistry classrooms.

DATA COLLECTION AND ANALYSIS

This study took place in General Chemistry I and General Chemistry II courses, titled CHM 11100 and CHM 11200, focused on College of Agriculture and College of Health and Human Sciences students. The CHM 11100 course has a requirement of two years of high school algebra, and the CHM 11200 course requires a grade of D or better in CHM 11100. Both courses meet for two lectures a week, a recitation, and a 3 hour laboratory session. In Fall 2021, all course meetings returned to an in-person format, as they were prior to the COVID pandemic. Enrollment is approximately 1000 students in the fall semester and 800 in the spring.

To understand the impact of COVID on high school chemistry laboratory experiences and subsequent downstream effect on college chemistry laboratory readiness, we used a classroom action research framework where the focus was on conducting research in the classroom with the goal of gaining insights and improving teaching practices and student learning.¹⁵ A survey was developed and deployed through Qualtrics within Purdue's learning management system (LMS) in Fall 2021 and Fall 2022. Students were asked to report how many hands-on face-to-face chemistry laboratories were completed in their first-year high school chemistry course. The students had the following choices: 0, 1–5, 6–10, 11–15, or more than 15. To facilitate analysis, students were asked their year in college at the time of the survey and the school year in which they were enrolled in their high school first-year chemistry course. These data facilitated grouping the students by undergraduate class and the phase of the pandemic in which the students had taken a first-year chemistry course. The analysis of this data would allow for insights to emerge and teaching practices to be adjusted, in alignment with the Action Research Framework.

Based upon the challenges observed in the Fall 2020 through Fall 2022 for students, data was collected that could be analyzed to identify potential solutions and support student success. In Spring 2022, students who responded to the following prompt via a Qualtrics survey deployed in Purdue's LMS: "Given your experiences in CHM 11100 and CHM 11200, what would you tell incoming freshmen to help them succeed in these chemistry courses?" The goal was to analyze the responses to generate suggestions and recommendations from student voices that could support student success in the subsequent semesters. This analytical approach is in alignment with the classroom action framework and the goal of leading to improved teaching practices and student learning.

Quantitative Analysis

To understand the analysis of the quantitative data pertaining to laboratory, it is helpful to review the sequence of the pandemic and its impact. Academic year 2018–2019 was a "normal" year. However, 2019–2020 was impacted by a lockdown and pivot to remote learning beginning in March of 2020 for most (nearly all) students in the United States. In academic years 2020–2021 and 2021–2022, state level mandates and district level decisions shaped in-person instructional decisions.¹⁶ This produced a wide variety of high school educational experiences for students entering institutions of higher education in Fall of 2021 or Fall of 2022.

The Fall 2021 data was analyzed by first sorting the respondents by undergraduate class and focusing on freshmen in the course, yielding a population of 666 students. The respondents were then sorted by the year in which they took a first-year high school chemistry course. The number of students who took chemistry in each academic year is shown in Table 1, along with the percentage of students who reported completing 0, 1–5, 6–10, 11–15, or more than 15 laboratories.

Table 1. Number of and Percentage of Fall 2021 Freshmen Reporting a Specific Number of Hands-on Labs in Each Academic Year

Laboratories completed in course/year course taken and N-respondents	2018–2019, no COVID impact, N = 530	2019–2020, pivot to remote learning in spring due to COVID, N = 114	2020–2021, remote learning due to COVID, N = 22
Zero	0.75%	3.54%	31.82%
1–5 labs	21.17%	38.05%	36.36%
6–10 labs	37.74%	34.51%	22.73%
More than 10 labs	34.34%	23.89%	9.09%

An identical analysis was carried out on the data collected in the Fall of 2022, yielding a population of 620 students. The number of students taking high school chemistry in each year is shown in Table 2, along with the percentage of students who reported completing 0, 1–5, 6–10, 11–15, or more than 15 laboratories.

Qualitative Analysis

Responses to the free response question from the Spring 2022 survey were open coded to identify themes responsive to the prompt. Delve,¹⁷ an online qualitative data analysis software, was used to create, sort, store, and retrieve codes/themes during analysis. After coding the responses, inter-rater reliability was performed to ensure reliability of the coding scheme. Two raters independently coded a random sample of

Table 2. Number of and Percentage of Fall 2022 Freshmen Reporting a Specific Number of Hands-on Labs in Each Academic Year

Laboratories completed in course/year course taken and N-respondents	2019–2020, pivot to remote learning in spring due to COVID, N = 484	2020–2021, remote learning due to COVID, N = 122	2021–2022, potential remote learning due to COVID, N = 14
Zero	3.31%	28.69%	7.14%
1–5 labs	50.62%	43.44%	35.71%
6–10 labs	32.23%	13.11%	28.57%
More than 10 labs	13.84%	14.75%	28.57%

60 responses each (120 total) out of the total 566 using the codes and definitions provided by one of the authors (MT). The raters agreed on 112 out of 120 codes, equaling 93.3% agreement. Discussion of coding disagreements then raised the percent agreement to 100%.

RESULTS AND FINDINGS

To understand the impact of COVID on the development of laboratory skills,^{18–20} it is helpful to plot the data in Tables 1 and 2 as the stacked bar charts shown in Figures 1 and 2. This allows the reader to compare the percentages of students in each year that completed five or fewer hands-on laboratories.

The concerning finding is that, prior to the pandemic in the 2018–2019 school year (shown in Figure 1), approximately 28% of the students completed five or fewer laboratories. In the 2020–2021 school year during the first full school year of the pandemic, the percentage completing five or fewer laboratories more than doubled to 68%–71% as shown in Figures 1 and 2. Notice the percentage of students reporting zero hands-on laboratories in both charts for 2020–2021 was approximately 30%. Although there may be an indication in the 2021–2022 data in Figure 2 that students may be completing more hands-on laboratories than the previous year, it lags behind the prepandemic data of 2018–2019. The data indicate that the disruption due to the pandemic has resulted in widely varying laboratory experiences for these students and points toward important implications for laboratory curricula in general chemistry programs.

Recommendations from Students

Based upon the analysis and interpretation of the free-response data, the top five themes that emerged are the following: Time Management, Attending Class and/or Lab, Using Resources, Navigating the Transition from High School to College, and Finding the Balance Between School and Your Personal Life. Discussing each allows for the use of student quotations from the survey to illustrate and contextualize a specific theme and to make connections between themes.

Time Management

The vast majority of students agreed that they wished they would have improved on some component of time management during their first year of college. Simply working on their time management skills was a piece of advice the following three students gave:

"I would tell them to learn how to manage their time well."

"Make sure to pace yourself and practice time management."

"Ha! There is so much homework you HAVE to know how to time manage."

Specifically, students repeatedly cited particular components of time management—the use of a planner, making a schedule, and staying organized. Planners were an element of time management the students identified as a helpful tool,

"Make sure you have a physical paper planner where you can write down and then check off all the assignments."

Aligned with these comments was the dominant reason for "knowing what is due when".

Students identified various platforms and methods to support time management and staying organized, from online tools and apps to one of the author's (J.G.R.) personal favorites—pen and paper. Regardless of the method used to keep a weekly planner, one of the clear benefits was assisting students' organization in completing assignments on time. Additionally, completing tasks in a timely manner across multiple courses and laboratories supports students' mental health by not falling behind.

Coupled with the use of a planner, students commented on the importance of finding strategies to stay organized. For example, one student wrote: *"I would tell them to make a spreadsheet of all their assignments to make sure you stay on top of assignments."* Another suggested, *"work out a system to study and*

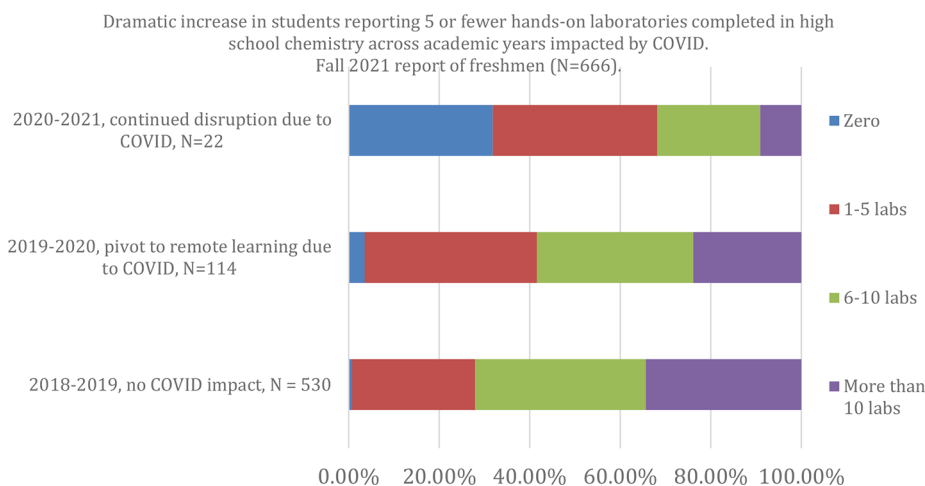


Figure 1. Data from Table 1 displayed as a bar chart to highlight the drastic increase in the number of students completing five or fewer laboratories (see the end of the red bar in each horizontal stack). Prior to the pandemic, in 2018–2019, it was slightly over 20%. This increased to over 40% to nearly 70% in the ensuing years.

Dramatic increase in students reporting 5 or fewer hands-on laboratories completed in high school chemistry across academic years impacted by COVID.
Fall 2022 report of freshmen (N=620).

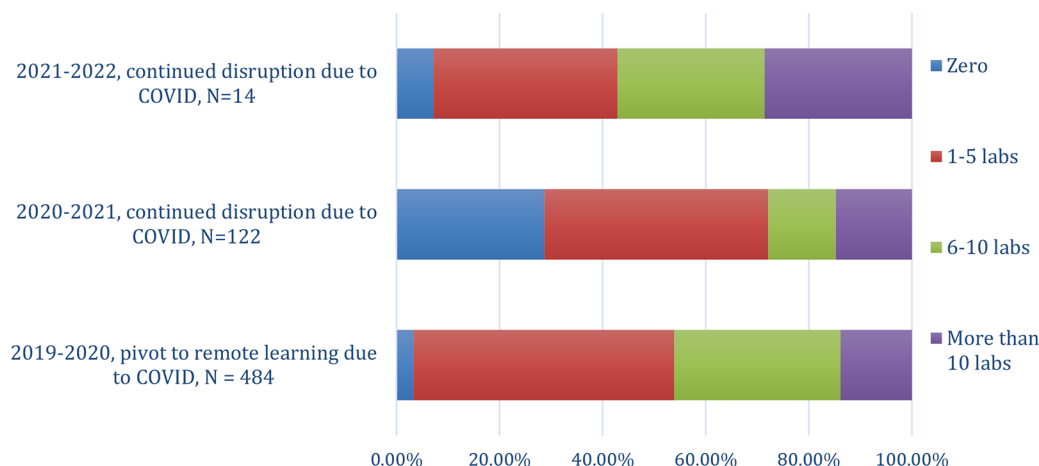


Figure 2. Data from Table 2 displayed as a stacked bar chart to highlight the drastic increase in the number of students completing five or fewer laboratories—see the end of the red bar in each horizontal stack. Note that the trend in the data during the 2020–2021 academic year shown in Figure 1 holds in Figure 2 where over 70% of the students report completing five or fewer hands-on laboratories.

complete assignments. This could be Google Calendar or a planner.” Others commented, “Write down which assignments are due and when they are due,” “Work out a system to study and complete assignments”, and “Make yourself a schedule.” Repeatedly students wrote about the need to find a way to stay organized. For some, successfully doing this was linked to mental health through comments such as “Do not fall behind and if possible, work ahead to limit the stress on yourself.”

Students also identified strategies leading to academic success that works for them, ranging from group work to taking a solo approach:

“I would definitely tell them to find a friend group in each class you are taking to help hold you accountable and encourage you to go to every class.”

“Start creating study guides and reviewing your notes at least a week before your exams.”

Time management skills and tools such as planners, being organized, and completing work on time are skills that translate from college into the real world and support student academic success and good mental health.

Attending Class

It is important to remember that, after nearly two years of remote learning experiences, attending class and sitting in a classroom for an hour (or more for the laboratory), is an activity that many students have engaged in with much less frequency during the pandemic. Findings indicate that if there is no attendance requirement in the course, then it is easier for students to make the decision to not attend and perhaps to tune in to the virtual lectures or recordings. However, the students indicated that the choice of not attending in person impacted their learning as the quote below demonstrates.

“It can be easy to slack off during the end of the semester/year, especially when certain classes have no attendance but there’s nothing like in-person classes. You learn the most while attending versus watching it online.”

Students recommended class attendance even if it is not required. Additionally, they noted that attending class was beneficial.

“Make sure to attend your class lectures, even if attendance isn’t required/monitored.”

“Go to recitations and classes because you are paying to go and they are helpful even if you find them boring there are always resources for people to help you so use them.”

Using engaging, diverse pedagogies and acknowledging that breadth of experiences through the pandemic that students are bringing to the classroom and laboratory can support student success and mental health.^{21,22} Focusing on helping students reconnect to the broader purpose and value of learning requires finding meaning, value, and relevance in their courses.

Resources

Prior to the pandemic, many college instructors emphasized that students should read the syllabus, ask questions and attend office hours, and utilize the institution’s resources for student success. Instructors should recognize that some students may face barriers to asking for assistance, such as schedule conflicts, prior negative experiences in office hours, or social stigma to attending.²³ It is important to emphasize that seeking assistance is a normal and valuable part of learning. Receiving feedback, coaching, and support is beneficial for everyone regardless of their level of expertise, and those positive effects can come from a variety of resources such as office hours, group study, supplemental instruction, etc.

As shown in the following excerpts, students recognized the importance of using the resources provided by the instructor and institution, including reading the syllabus, asking questions to the professors and/or teaching assistants (TAs), attending office hours virtually or in-person, and using supplemental instruction (SI).

“Be willing to ask questions and attend office hours when you start noticing yourself struggling before it is too late to make up for it.”

“Don’t be afraid to reach out. In college you have to put a lot more effort into your work and sometimes you get the same results. It can be scary to ask for help or reach out to your peers, but it is worth it.”

"It is also very important to not be afraid to ask questions, because people are there to help you and if you aren't comfortable to ask in person email is always great."

"Please, don't be afraid to ask for help!"

Students who had spent a year in college were strong supporters of making use of the resources instructors and the institution have to offer.

Navigating the Transition

Students also noted the differences between their habits in high school and how they could not carry those habits over into college, most notably in their learning:

"I would tell them to be prepared for a lot of new ways of learning and studying. Finding new friends is important, but do not forget about your studies and work hard because you are ultimately there for a degree, not just to have fun. I would also tell them to be prepared for much harder exams than you have experienced in high school."

Students faced a steep learning curve tapping into time management—college is more difficult than they expected, and time management was a shock:

"Be prepared to have no free time."

"I would tell the freshmen to be prepared to study way more than they did in high school and to be ready for exams that are much harder than they have taken before."

Thus, helping students navigate the transition between high school and college by acknowledging their breadth of experiences in the pandemic, emphasizing time management and organizational skills, the importance of attending class, and utilizing resources can support their academic success and their mental health and well-being.

Finding Balance

Students recognize that maintaining positive mental health is important and that managing time and completing assignments needs to be complemented by activities that lowers stress and bring enjoyment. Finding the balance between academic responsibilities, developing friendships, extracurricular activities, exercising, etc., was a challenge students identified.

"Make yourself a schedule with times to do work, exercise, hang out with friends, etc. There's going to be a lot more free time than you're used to and it's easy to ignore all your work and even personal needs since there's no one to hold you accountable anymore."

Thus, balance is related to managing time, which was a theme discussed previously. More than one student framed balance as managing time or defining priorities:

"With classes, work, clubs, friends, and extracurricular activities, you can often find yourself feeling overwhelmed, and this can impact mental and physical health. So I'd say to stick to your priorities and find time/alternatives for fun activities— it's all about balance, which can be hard when first coming to college."

"I would tell them that it was ok to go out and have fun with your friends, but they still needed to take time to study and do good in their classes and get their assignments done."

"Time management will help you make sure you have enough time to complete assignments, study, eat, and keep a healthy balance of fun activities to ensure you have the highest success possible."

Making students aware of resources that promote balance between academics, physical and mental health, and all the resources that the institution has to offer can support student success. The themes of finding balance, time management, and

accessing resources act synergistically to support academic success and mental health and well-being. Together, these recommendations represent authentic student voices and recommendations that can be leveraged in the classroom to recognize student needs and to support them in their success.

DISCUSSION AND IMPLICATIONS

These findings provide insights into the impact of COVID-19 on high school chemistry laboratories and the downstream effects on college chemistry laboratory readiness. The findings also provide recommendations for supporting student learning in classrooms based upon student suggestions. Emerging evidence from K–12 student learning studies show significant negative impacts on learning related to the pandemic.^{1,2} Further analysis of the emerging evidence reveals disparate impacts across groups, especially impacting students that identify as PEERs.^{1,2,24} These impacts, the unfinished learning, and disrupted and disparate learning experiences are carried into chemistry classrooms by incoming students. Synthesizing these findings with the research on communication during the first day of class²⁵ suggests that it is beneficial to acknowledge students' pandemic related experiences. This action conveys an understanding of their situation and can emphasize the availability of academic and well-being resources to support students. Reminding students of available (free) resources, incentivizing their use, and normalizing help seeking can improve academic success, connection to peers, sense of belonging, and mental health.^{23–25}

The analysis and interpretation of the data collected in this study can be used to guide the laboratory curriculum and what instructors can do on the first day of class to prioritize talking points and support to students.²⁵ Given the findings of this study and the literature pertaining to the first day of class activities, college chemistry instructors are encouraged to support student learning in the laboratory by developing a plan to enhance laboratory knowledge around safety, recognition of glassware/equipment and its use, techniques, and reasoning. Digital badging to improve students' hands-on laboratory skills has been shown to be effective in enhancing students' knowledge, confidence, and experience, and articles within this journal provide guidance.^{26–29} Although before the pandemic chemistry instructors may have had concerns about readiness for laboratory activities, the analyses herein show a sharp decline in the number of laboratory activities that students experienced in high school and a pedagogical and curricular response is warranted.

For institutions that employ laboratory teaching assistants (graduate or undergraduate), training that emphasizes good laboratory practices and techniques, safety, patience, and empathy toward the students is crucial as the analysis demonstrates that students impacted by the pandemic have a marked decrease in laboratory experiences in high school. Demonstrating how to appropriately use glassware/equipment and how to engage in appropriate safety protocols is foundational in helping students develop knowledge and confidence in their laboratory practices. To decrease student anxiety while describing laboratory expectations, instructors can discuss the laboratory curriculum and environment, including the roles the instructor and teaching assistants have in providing support in the course.²⁵

The results of this research also provide guidance for college chemistry instructors to support students' time management and study skills. There are a variety of options instructors can

implement such as creating weekly planners distributed through a Learning Management Systems (LMS) as either standalone documents or videos. A weekly planner can communicate lecture and lab topics, readings, due dates, quizzes or exams, etc. It may help students develop organizational skills, and it signals to the student that the instructor believes this is an important component of academic success. Instructors can also create study guides, concept maps, or any form of aid or supporting information to help students learn the material. Research demonstrates that effective study skills may not be aligned with typical student practices such as watching the lectures repeatedly or reread their notes.^{30,31} Retrieval skills have been shown to be more effective in producing meaningful learning gains,^{30,31} thus engaging in the principles of retrieval practice and in-class problem solving may help students develop those skills.

LIMITATIONS

The data gathered in this report is derived from large lecture general chemistry courses and may not be representative of student experiences at smaller colleges or universities in states that experiences a lesser degree of disruption during the pandemic. Further, there may be concerns related to the validity and reliability of student report data regarding laboratories, and what is defined as a hands-on laboratory. We encourage other faculty to expand upon the data found in this report for the purposes of describing the pre and postpandemic landscape.

It is clear from the emerging data around the impacts of COVID on education that disparate impacts exist based upon race and socioeconomic status. However, within this report, data was not collected pertaining to race, ethnicity, or the location of the students' high school. Thus, connections cannot be made between the data in this report and the emergent research about those impacts.

CONCLUSION

This report and emerging research suggest that the COVID-19 cohort of students in classrooms and laboratories are different than the students who arrived prior to the pandemic. The impact of COVID-19 will be long-lasting on students as well as faculty and staff. Chemistry instructors have an important role to play in acknowledging the challenges students face and in offering the best support to keep them on track and help them succeed in chemistry, college, and life post-COVID.

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Notes

The authors declare no competing financial interest.

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